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Application of Coded Wire Tagging Technology in Pacific Herring to Investigate Stock Structure and Migration

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Tagging of Pacific herring in British Columbia has a long history dating to the mid-1930s but uncertainty in tag recovery locations and low tag return rates limited the utility of these studies. Currently, a larger and more stringent Pacific herring tagging data set is desired to monitor the movement and mixture of fish interannually. From 1999 to 2001, a program was implemented employing coded wire microtags to mark Pacific herring on the spawning grounds.

Methodologies for capturing, holding, tagging and releasing tagged herring were developed during coded wire tag insertion trials. Tag detection tubes designed for recovery of tagged Pacific salmon were adapted to detect and recover CWTs in fish plants during herring roe extraction processing. Screening of commercial catches from five coastal regions was conducted in 2000, but in 2001, screening of catches from only three regions was conducted due to closures in two regions. Out of 558 interannual tag recoveries, four remarkable strays were recovered from 461 one year at large recoveries and no strays were recovered from 97 two year at large recoveries.

Recovery rates were derived for reference purposes to characterise efficiencies in acquiring tag returns. From both 2000 and 2001 tag returns, one year at large recovery rates ranged from 0.07 to 0.3% (0.3 to 1.1% when adjusted for screening coverage) and two year at large tag return recovery rates were approximately 0.2 % (0.7 to 0.8% when adjusted for screening coverage). Pacific herring CWT data will eventually be integrated with other sampling data describing Pacific herring stocks. Field trials indicated the feasibility of cost effective application of large numbers of tags during short spawning seasons and captivity trials indicated high survival and low tag shedding after coded wire tag insertion. Coded wire tagging technology appears to be useful for large scale marking experiments on smaller pelagic species. Results and methods from these approaches should have broad application for stock structure and mark-recapture studies.

Keywords: coded wire tags, recovery, Pacific herring, stock structure, tagging.

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INTRODUCTION

Since the 1930's, tagging data on Pacific herring (*Clupea pallasi)* in British Columbia (BC) have been collected and used to understand various components of stock structure and behavior, such as migration and interannual straying. An understanding of the spatial structure and degree of independence of fishable production units is critical to the effective management of the herring resource. Currently, five major geographic stocks of herring are identified for fishery assessment and management. The five stock regions are the Queen Charlotte Islands, Prince Rupert District, Central Coast, Strait of Georgia, and west coast of Vancouver Island, Figure 1 (Schweigert, Fort and Tanasichuck, 1999; Schweigert and Fort, 1999; Schweigert, 2000; Hamer and Hepples, 2000 and 2001).

In recent years (1999 to 2001), coded wire microtags (CWTs) have been used to mark mature herring caught in commercial roe herring fisheries during spawning periods from February to April. Prior to the use of CWTs, tagging was done to study several aspects of Pacific herring biology and mark and recapture efforts were often done outside of spawning seasons. From 1936 to1967, tagging experiments used metallic internal belly tags which were inserted into the body cavity (Hart and Tester, 1937-1940; Hart *et al*., 1941 and 1942; Stevenson, 1950; Stevenson *et al.*, 1952 and 1953; Stevenson and Lanigan, 1951; Stevenson and Outram, 1953; Taylor, 1955; Taylor *et al*., 1956 and 1957; Taylor and Outram; 1954; Tester, 1944-1946; Tester and Boughton, 1943; Tester and Stevenson, 1947 and 1949). From 1979 to 1991, herring were tagged with Floy anchor tags made with a plastic tube attached to a monofilament T-shaped end that was inserted into the dorsal musculature (Armstrong *et al*., 1990; Farlinger, 1986, 1988, 1989a, 1989b; Farlinger *et al.*, 1991; Haegele, 1981, 1984a, 1984b, 1984c and 1986; Haegele and Hopwo, 1984; Haegele *et al*., 1982a, 1982b, and 1983; Hay et al., 1999; Hourston, 1981). The automated technology for tagging herring with CWTs is extremely efficient compared to inserting metal belly tags or plastic Floy anchor tags. The approaches that were used for recovering belly tags and anchor tags differed considerably. Recovering belly tags relied on metal detection devices or magnetic attraction in processing plants whereas recovering anchor tags depended on visual detection by fishing crew and plant workers (Hart and Tester, 1937-1940; Haegele et al., 1982b; Haegele et al., 1983; Haegele, 1984a). The logistics used to detect and recover CWT samples were quite similar to historic induction methods of recovering internal belly tags. Both recovery systems were designed to detect metal signals and divert samples during product conveyance in fish plants. (Hart and Tester, 1937-40). Uncertainty in some tag recovery locations and low recovery rates has limited the use of the results from belly and anchor tagging. The reliability and access of fishing and processing records in BC have evolved considerably since the use of belly and anchor tags as a result of newer management strategies. Current methods of managing roe herring fisheries are beneficial for relating tag returns to relatively precise catch dates and locations within individual fishery openings. Automated equipment was developed and installed in two plants in 2000 and three plants in 2001 to efficiently detect and recover marked herring with CWTs.

In this paper, the methods which were applied for catching, tagging, and releasing Pacific herring for interannual CWT studies are presented along with the methods for screening commercial harvests and recovering herring CWT samples. The results include the outcomes from the 1999, 2000 and 2001 field tagging efforts and the 2000 and 2001 processing plant tag recovery efforts. The period of time between release and recapture events is referred to as time at large. Two types of recovery rates describing tag returns were derived from the number of tags released or the tonnes of roe herring screened and comparisons were made among different sets of release and recovery data. Only preliminary analyses of recovery rate data has been attempted because the current Pacific herring CWT data set is fairly small. This report also includes an appendix that describes the outcomes of a complementary captivity study undertaken to assess effects of tag insertion on relative mortality, tag retention and incidence of scale insertion.

METHODS

Tagging and releasing herring with CWTs

Regional coverage: Herring CWT capture and release efforts to date occurred in the Strait of Geogia (1999, 2000 and 2001), the Queen Charlotte Islands (1999) and the Prince Rupert District (2001). Efforts to catch and tag fish in the Central Coast region were made in 2001, but the seasonal timing and behavior of fish schools were not favourable for tagging. The number of days per tagging charter period were 24 (in 1999) and 30 (in 2000 and 2001). These periods included a day or two of setting up and dismantling tagging equipment, days spent travelling or avoiding hazardous weather and days when no fish were caught. Results of tagging efforts from 1999 to 2001 are related to 14, 18 and 16 actual tagging days, respectively.

Catching and holding: Several arrangements for capturing, tagging and releasing herring have been tried during the three field seasons of 1999 to 2001. All fishing efforts used purse seines to capture herring and three different net sizes have been employed. Most fishing was done with nets of 183m x 17m (small) or 274m x 27m (medium) and in a few cases commercially sized nets of approximately 410 m x 70-80 m (large) were used. Surplus fish to the needs of a tagging session were released from sets that had catches greater than approximately four tonnes. This was done to prevent undue fish stress from excess fish held in a net alongside the vessel during a tagging session. When fishing was done with a small or medium net, untagged fish were held partly dried up in the bunt along the starboard side of the tagging vessel. When a commercial sized net was used a small fraction of the catch was brailed from the haul and placed in a floating and tethered cylindrical accessory pen which was brought alongside the tagging vessel. Dipnets of herring were then manually removed from the partially dried up net or accessory pen and distributed to the tag injector stations (Figure 2). To avoid risks of high mortality from the effects of retaining and handling herring during tagging sessions, a reoccurring "fish stress" observation was used to indicate when to discontinue tagging sessions. This observation related to when fish started showing signs of losing slime and thus felt relatively rough when handled. This generally occurred 1.5 to 3.0 hours into a tagging session depending on events affecting the fish in the net, such as sea state or sea lion interference.

Tagging and biological sampling: Several types of equipment and methods were tried over the three seasons of herring tagging work. Northwest Marine Technology (NMT) Mark IV Automatic Coded Wire Tag Injectors with 8.9 cm (3.5 inch) long tagging needles and 1.5x standard length (1.8 to 2.0 mm) binary CWTs were used each year. The DFO Salmon Mark Recovery Program supplied the Pacific Herring CWT Program with leftover salmon tags. Spools of wire were proofread before and after field use to clarify discrepancies in tag code records. In 1999, CWTs were inserted into either the tissue directly behind the skull (commonly referred to as the middle neck or nape sites) or into dorsal musculature adjacent to the dorsal fin (commonly referred to as the mid dorsal, back or lower back sites). In 2000 and 2001 tags were only inserted into the nape site. All tag injections were fitted with a brass needle support with an oblique surface, (Figure 3), to support fish bodies while tags were inserted. Several tagging sessions conducted in 1999 and 2000 incorporated trials with anasthetics but in 2001 none of the herring were anasthetized. A limited number of biological samples each year were collected for age, length, weight and DNA information to complement some of the sets. Information from these samples is not incorporated in this report.

Tag injectors were mounted on tables aboard each vessel and trigger buttons were operated by either foot (1999) or knee (2000 and 2001). In 1999, two tag injectors and operators were used for the tagging fieldwork; in 2000, four tag injectors were used and in 2001 three injectors were used. On days when mature herring were caught for tagging, up to three tagging sessions were conducted. A tagging table was designed for the 2000 season by Thyra Nichols of Streamline Consulting to maximise work space and efficiency for up to four tag injectors and operators (Figures 4 and 5). The table, which was installed on the 2000 and 2001 tagging vessels, was rectangular (1.2 x 2 m) and made of plywood (with a fibreglass finish) and had two components, an upper manifold and a lower table surface. The upper manifold received each dipnet of fish and had chutes that guided fish to a mesh–lined basins at each tagging station. The lower table surface provided the space for tag injectors as well as held terminal pieces of 15 cm diameter PVC piping to convey tagged fish. The piping from each station converged to a main stem that contained flowing seawater pumped through to direct fish (along with gravity) overboard for release purposes (Figures 4 and 5). In 1999, the two tag injector operators manually released tagged fish overboard. When predators, such as sea lions or sea birds, were notably present or when an anaesthetic had been used, tagged fish were released into a recovery pen. The pen helped promote re-schooling and protected tagged herring against predators. The recovery pen was 1.8m square on top, tapering to 1.2m square on the bottom and was made of perforated canvas with two 30 cm square escape doors (Figure 5).

Screening roe herring harvests and recovering herring with CWTs

<u>Basic design and operation of recovery units:</u> Considerable effort was taken to design and implement effective herring CWT recovery systems. The fundamental components in the design of a herring CWT recovery unit were: an R9500 Detector (supplied by NMT), a

conveyor belt, an aluminium frame manifold, a deflector gate system and controls for setting the rates and sensitivities of a unit's operation (refer to Figure 6). A recovery unit's conveyor system can be aligned in series or in parallel to a plant's conveyor system. Each system's conveyor guided fish through the R9500 Detector for metal detection of the CWTs. When a threshold signal was detected then a diverting gate system downstream of the detector box was triggered and a collection of fish from the unit's conveyor was deflected through a chute into a collection tote. Once deflected to a tote, carcasses were manually screened to locate the fish with the metallic signal. Initial trials following the construction of the first CWT recovery unit were designed to try to screen herring offloads as fish were being offloaded from vessels and along plant conveyors. Several difficulties arose related to the recovery equipment's ability to accommodate the 30 to 110 tonnes of fish per hour. Test trials were also conducted during processing activities from a December 1999 Special Use Herring Fishery (Z licensed for food or bait) with conveyance rates of 6 to 10 tonnes per hour and the unit had no problem accommodating loads of fish.

In 2000, the decision was made to screen herring at plants during the roe processing activities.
The herring that were screened were offloaded and retained in cold brine for up to several weeks before processing steps sorted sexes, cut fish, removed gonads and used non-roe products for fishmeal. Conveyor rates and fish loads during these activities were commonly between 8 to 20 tonnes of fish per hour. Expected benefits from this decision were that fewer equipment malfuncions would occur due to the lower conveyor loads and screening would be more thorough with less strain on equipment and staff.

<u>2000 and 2001 roe herring harvests and CWT screening coverage</u>: In 2000 and 2001, tagged herring were captured by seine or gillnet vessels along the BC coast during roe herring fishing opportunities which occurred over several days from the end of February through to April. Only a fraction of the BC roe herring regional harvests were screened for CWTs at processing plants. In 2000, roe herring fishing occurred in all five BC stock assessment regions and in 2001, the Queen Charlotte Islands and the west coast of Vancouver Island were closed due to conservation concerns. Further details regarding the 2000 and 2001 roe herring fishing seasons can be found in Hamer and Hepples (2000 and 2001). In addition to BC roe herring landings, portions of Alaska's Sitka roe herring catches have also been processed and screened for CWTs at BC fish plants.

Recovery unit locations, supervision and screening periods: Ongoing screening for herring CWTs began in 2000 using two recovery units placed in two fish plants in the Vancouver Lower Mainland, namely Icicle Seafoods (Icicle) and Canadian Fishing Company (CFC). In 2000, a thrid recovery unit was in operation at the Lower Mainland Bella Coola Fisheries plant (Bella Coola). CWT screening at plants in 1999 and 2000 occurred from April to June, over a 9 and 10 week period, respectively. Staff members from the Vancouver based consulting company J.O. Thomas and Associates were employed to: operate recovery units; collect and handle samples; record results of equipment operation; verify catch information related to fish lot processing records; and communicate with plant staff (for trouble shooting and resolving equipment problems). It was required that operating tasks associated with the CWT screening include testing each unit under different settings using seeded trials with eirther rubber decoy CWT fish or actual herring carcasses doubly marked with a CWT and a highly visible Floy anchor tag. Selecting and maintaining optimum settings for metal detection and deflector gate responses at the different plants was an important part in the CWT screening process. Records were kept for conveyor speeds, number of fish diverted by the gate and false positive responses from signals other than CWTs.

Recovering CWT samples and compiling data: Sample collections, laboratory CWT dissections and sample analyses were undertaken in addition to the operation of the recovery units. In 2000, all herring specimens recovered with a metal signal were brought to the laboratory for dissection and many samples contained a metal signal from a metallic source other than a CWT. In 2001, each specimen emitting a metallic signal for the recovery unit to detect was rinsed in water and had its gills removed to try to reduce the number of false positive specimens requiring laboratory dissections. When a specimen still provided a signal strong enough to be detected by the recovery unit, the sample was kept for laboratory processing. Coded wire tags were removed from herring bodies and codes were read and recorded on a spreadsheet. Other recorded information included source vessel names and product lot numbers which provided information on the date and catch locations. Recovery information was compiled by J.O.Thomas and Associates for use by the Department of Fisheries and Oceans to relate with CWT release records for preliminary analyses. All recovered CWT samples were proof-read by a DFO staff member to ensure code identity.

Raw and adjusted recovery rates and CWT harvest estimates

Pacific herring CWT recovery rates and harvest estimates: Several calculations were used to provide either recovery rates or estimates of the total number of tagged herring that may have been caught in roe herring harvests. The calculations used data from 1999 to 2001 tagging results and 2000 and 2001 harvesting and screening results. Two formulae were used to derive herring tag recovery rates. One formula related numbers of tag returns to numbers of tags released (this rate was a percentage) and the other formula related numbers of tag returns to quantities of roe herring screened (this rate was a ratio of tags to tonnes). Both types of recovery rate data were adjusted to factor in proportions of regional harvests that were screened by CWT recovery equipment, thus a set of adjusted recovery rates were produced. For short term (in-season) recoveries, recovery rates relating the number of tag returns to the number of fish tagged were not calculated because determining instantaneous tag release estimates in relation to seine or gillnet fishing periods would be quite complicated. Estimates were determined ofthe number of tagged fish that may have been harvested by factoring in the proportions of regional harvests that were screened for CWTs.

RESULTS

Tagging and releasing herring with CWTs

The total number of BC Pacific herring that were tagged and released from 1999 to 2001 is 451,032 (Table 1 and Figure 1). In 1999, 47,712 and 6,175 herring, were tagged in the Strait of Georgia and Queen Charlotte Islands, respectively. In 2000, 248,391 herring were tagged in the Strait of Georgia and in 2001, 60,558 and 88,196 herring were tagged in the Strait of Georgia and Prince Rupert District, respectively. The number of tagging sessions (or sets) from 1999 to 2001 were 19, 32 and 36 sets, respectively. Unfortunately, two tag code discrepancies resulted from typographical errors and mislabelling of 1999 and 2000 tag code records. The discrepancies relate to cases where codes first used in the Strait of Georgia in 1999 were reused in the Strait of Georgia in 2000. From the 2000 recoveries, tag returns can be related to 1999 release events because accidental code reuse did not occur until after the 2000 recapture events (roe fisheries). In total, 7,141 herring were tagged with the two codes relating to the 15 recoveries with year discrepancies; 4,444 of which were released in 1999 and 2,697 of which were released in 2000. For the sake of simplifying analysis of year 2001 recoveries, the number of releases and recoveries pertaining to year discrepant codes are removed from the totals when calculating recovery rates.

Screening roe herring harvests and recovering herring with CWTs: Annual BC harvests of roe herring, including test-fish payments, were 29,118 tonnes in 2000 and 24,006 tonnes in 2001 (Hamer and Hepples, 2000 and 2001).

Information of the amount of catch screened by year region is presented in Tables 2 and 3. In 2000, 6,222 tonnes were screened for CWTs, which equalled approximately 21% of the BC total catch. The screening coverage for individual regional harvests was: 23 % Strait of Georgia; 20% west coast Vancouver Island; 29% Central Coast; 8 % Queen Charlotte Islands and 10% Prince Rupert District. In 2001, 6,922 tonnes were screened for CWTs, which was approximately 29% of the BC total catch. The screening coverage for individual regional harvests was: 28% Strait of Georgia; 39% Central Coast, and 9% Prince Rupert District. The amount of Sitka caught roe herring that was screened during 2000 and 2001 processing activities weas 680 and 661 tonnes, respectively.

Summary results of the 2000 and 2001 Pacific herring CWT returns are listed in Table 4. In 2000, there were 531 tagged herring recovered from the releases of 1999 (n=127) or 2000 (n=404). In 2001, there were 577 tagged herring recovered from the releases of 1999 (n=97), 2000 (n=334), 2001 (n=131) or release year discrepancies (n=15). With the exception of 4 recoveries, all tagged herring were re-captured in the same stock region where they were tagged. These 4 recoveries signify one year at large regional straying (no two year at large strays were observed). From the 2000 recoveries, two fish that had been tagged in the Strait of Georgia in 1999 were re-captured by a herring test-fishing boat in Sydney Inlet (west coast of Vancouver Island, Statistical Area 24) and one fish tagged in the Queen Charlotte Islands in 1999 was re-captured in East Higgins Passage (Central Coast, Statistical Area 7). In 2001, one fish that had been tagged in 2000 in the Strait of Georgia was re-captured in Spiller Channel (the Central Coast, Statistical Area 7). In 2000, there were 695 false positive CWT recoveries analysed in the laboratory and in 2001, there were 299 false positive CWT recoveries analysed in the laboratory.

Raw and adjusted recovery rates and CWT harvest estimates: The input data and results related to Pacific herring CWT recovery rate calculations are presented in Tables 5 and 6. Some interannual recovery rate trends were apparent although variable estimates were achieved by incorporating or omitting certain regional associations into calculations. In comparing one year at large recovery rates between 1999 and 2000 Strait of Georgia releases, the 1999 releases had higher raw and adjusted rates relating the number of recoveries to both the number of tagged fish released and to screening coverage, although the latter rates were quite comparable. The 1999 Queen Charlotte Islands releases had one year at large adjusted recovery rates comparable to one year at large Strait of Georgia releases for both types of recovery rates when calculations used only Queen Charlotte Islands screening data. But raw recovery rates from the Queen Charlotte Islands were considerably lower. There were no Queen Charlotte Islands roe herring harvests in 2001, and so no two year at large Queen Charlotte Islands tag recoveries to compare with Strait of Georgia rates. In comparing recovery rate results between one and two year at large Strait of Georgia releases, the two year at large raw and adjusted rates related to the number of tagged fish released were very comparable and intermediate to the 1999 and 2000 one year at large rates. However the rates relating the number of recoveries to the screening coverage are consistently lower than the one year at large figures for both raw and adjusted rates. The raw and adjusted recovery rates relating the number of in-season recoveries to the tonnes screened for CWTs within a single region (Strait of Georgia or Prince Rupert District) were considerably higher than any of the interannual rates, especially for Prince Rupert District recoveries.

Benchmark figures for estimating the quantity of tagged herring harvested from defined regional fisheries were derived by adjusting the number of tag recoveries to reflect proportions of screening coverage per fishery (Table 6). The estimates for the harvesting of 1999 Strait of Georgia one year at large releases ranged from approximately 500 to 600 herring, whereas the estimates for the harvesting of 1999 Queen Charlotte Islands one year at large releases were 20 and 51 herring. The three estimates for the Strait of Georgia one year at large releases ranged from 1,060 to 1,170 herring. The two estimates for the harvesting of Strait of Georgia two year at large releases were approximately 340 herring. The estimate for the harvesting of 2000 in-season Strait of Georgia releases was 1784 herring. The estimates for the harvesting of 2001 in-season Strait of Georgia and Prince Rupert District releases combined ranged from 569 to 792 tagged fish, whereas individually, the Strait of Georgia estimate was 295 and the Prince Rupert District estimate was 497.

DISCUSSION

Coded wire tagging and recovery unit operations designed for Pacific herring are versatile and are proving to be very effective and practical mark-recapture approaches for tagging and screening large quantities of fish. Coded wire tag technology certainly maximises tagging production with perceivably less trauma on fish than the use of Floy anchor tags or metal belly tags during the limited tagging periods available after herring are captured. Utilising experienced staff to conduct sea trials and improve capturing, holding and tagging methods was important especially for reaching goals of tagging quality, efficiency and proper fish handling care. The in-season recovery data are useful for evaluating how many tagged herring were immediately removed thus reducing the pool of tagged herring available for recovery in subsequent years. Tagging herring in a region before and during roe herring fisheries still appears to be worthwhile even if the estimates of Table 5B greatly underestimate the true quantities of in-season tagged herring collected (Schweigert and Flostrand, unpublished data).

The screening coverage for roe herring harvests is something that deserves considerable attention. Relating recoveries from proportions of catches screened to stock abundance estimates should assist in developing models and describing interannual spawning migration rates. So far, the most thorough screening coverage for CWTs has been from the Central Coast and Strait of Georgia regions and efforts will be made to take advantage of opportunities to screen a higher proportion of herring caught in the Prince Rupert District and Queen Charlotte Islands. The two strays found in the Central Coast and the two strays found in the west coast of Vancouver Island are evidence that representative strays can be found when regional catches are thoroughly screened. One hundred percent CWT screening of the 2000 and 2001 roe herring harvests was not feasible because the costs of constructing and operating CWT recovery equipment are very high and the logistics to implement these steps are quite complicated. Furthermore, much of the vessel offloading activities occur simultaneously at many sites in the province as do roe processing activities later in the season. Although the number of tag returns from screening 100% of roe herring harvests can be estimated, those figures can not provide any information on anomalous straying. More extensive recovery data would assist in formulating straying rate information. Despite the feasibility to screen roe herring for CWTs, conservation concerns that result in regional fishery closures have the most direct limiting impacts on screening opportunities. It is unfortunate that 2001 fishery closures in the Queen Charlotte Islands and west coast of Vancouver Island compromised screening coverage.

The precision and accuracy of individual commercial vessel fishing locations are often limited to the boundaries of the fishery openings. Vague or inaccurate locations within the boundaries of the opening especially result because packer vessels collect roe herring from multiple hauls during each opening. This puts some constraints on trying to characterise school movements within a spawning season and on determining homing fidelity to spawning grounds within a region.

Good communication and cooperation with fish plant staff for tag recovery efforts has been fundamental in assuring recovery opportunities. For all screening trials, the fish plants that housed the CWT screening equipment were selected based on individual annual production expectations from operational plans. Production goals and capacities of each plant were fairly defined before each roe processing screening period, although there was some uncertainty in estimated quantities of roe herring able to be screened from different stock regions. The 93% and 75% screening coverages within each plant are quite reasonable when one considers that some plants pre-sort males (thus male fish bypass roe processing) and that plant activities do not stop when recovery units malfunction.

The two types of recovery rates which were derived in this study and which are presented in raw and adjusted form represent two complementary ways of quantifying the data. One type reflects the catchability of tagged herring with respect to the number of tagged fish released and the other reflects the frequency in which recoveries are found from the extent of screening coverage. Thus, there is no direct correlation between these two rates (Tables 5 and 6). The adjusted rates factor in the proportions screened from regional catches as a means of standardising both types of rates for making more thorough comparisons. The derived tag recovery rates may give us survival and straying rate estimates for incorporating into future stock assessment models. Especially since regional catches of roe herring in BC currently reflect relative stock sizes based on an approximate total allowable harvest rate of 20% (except for cases where a region was closed due to conservation concerns).

The CWT work on mature herring is part of a larger effort to investigate stock structure in conjunction with genetic analyses and historical tagging data. As the Pacific herring CWT data set grows, the data is expected to lend itself to several types of important analyses. Future management of tag codes will aim to use a different set of codes for each tagging session to enable comparisons among recovery rates related to different tagging crews, herring demographics or field conditions. Records of field conditions and results from representative biological sampling should assist in developing models for estimating abundance and mortality and describing interannual spawning ground migrations.

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Table 1. Summary results of tag and release trials using CWTs with Pacific herring from 1999 to 2001 in British Columbia. SG = St of Georgia; QC = Queen Charlotte Islands; PR = Prince Rupert District.

Year	1999	2000	2001	Total
Regions	**SG & QC**	**SG**	SG & PR	
Tags released	**SG 47,712 QC 6,175**	**248,391**	**SG 60,558 PR 48 K**	**451,032**
Tagging days	**14** SG 11 QC 3	**18** SG	**16** SG 7 & PR 9	**48**
Charter days prep, weather, travel	**24 SG 19 & QC**	**30** SG	**30** SG 12 & PR 22	**84**
Tagging sessions	**19** SG 16 & QC 3	**32**	**36** SG 17 & PR 19	**87**
Sessions per day on grounds	**1 - 2**	**1 - 3**	**1 - 3**	

Table 2. Summary results of 2000 and 2001 CWT screening coverage. SG = St. of Georgia; PR = Prince Rupert District; CC= Central Coast BC= Bristish Columbia; Sitka = Alaska; N/A = not applicable

Year	1999	2000	2001
Recovery units	*test trials*	**2**	**3**
Screening period	N/A	**8 - 9 weeks April 3 – June 14**	**7 - 10 weeks** April 2 – June 29
Screening amount -tonnes	N/A	**6,222** BC (+ 681 Sitka)	**6,922** BC (+ 661 Sitka)
BC roe herring -tonnes harvested	**28,734** **5 regions**	**29,118** 5 regions	**24,006** **SG, PR & CC**
Catch proportion screened	N/A	**21%** (QC 8% - CC 29%)	29% **(PR 9% -** CC 39%)

Table 3. Summaries of harvests and CWT screening by year and stock region.

Stock region	Processed at CFC & Icicle	CWT Screened*	% CFC & Icicle screened	Total catch	% catch screened
Year 2000					
SG	3,493.9	3,182	**91%**	14,048	**23%**
WCVI	339.2	333	**98%**	1,627	**20%**
CC	2,260.0	2,156	**95%**	7,365	**29%**
QCI	138.6	138	**99%**	1,764	**8%**
PRD	467.0	413	**88%**	4,315	**10%**
Sitka	715.8	680	**95%**	n/a	**n/a**
BC Coast	**6,698.8**	**6,222**	**93%**	**29,118**	**21%**
with Sitka	**7,414.5**	**6,902**	**93%**	**n/a**	**n/a**
Year 2001					
SG	5,475.1	4,257	**78%**	14,957	**28%**
WCVI	0.0	0	**n/a**	0	**n/a**
CC	3,084.0	2,389	**77%**	6,130	**39%**
QCI	0.0	0	**n/a**	0	**n/a**
PRD	279.4	276	**99%**	2,917	**9%**
Sitka	1,622.8	661	**41%**	n/a	**n/a**
BC Coast	**8,838.5**	**6,922**	**78%**	**24,005**	**29%**
with Sitka	**10,461.3**	**7,583**	**72%**	**n/a**	**n/a**

* Both years, CWT screened estimates derived from JO Thomas and Associates

The 2000 data contains three revisions from Table 3, Schweigert and Flostrand (2000): The conversion to metric tonnes from short tons was corrected using 0.9072 (not 0.9702); this table's total regional catch amounts includes test fishing charter payment harvests; whereas the previous table did not and the total amount screened for PRD was corrected.

Table 4. Summary results of 2000 and 2001 CWT recoveries. SG = St of Georgia; CC = Central Coast; QC = Queen Charlotte Islands; WC = west coast Vancouver Island; N/A = not applicable. Strays bracketed and denoted by an asterisk.

Year	**2000**	**2001**	**Total**
Tag returns	**531 (3)**	**577 (1)**	**1093 (4*)**
1 year at large	**SG 122 (2*)** 2* SG -> WC **QC 5 (1*)** 1* QC -> CC	**SG 334 (1*)** 1* SG -> CC	**461 (4*)**
2 year at large	**N/A**	**SG 97 (0)** **QC 0**	**97 (0)**
Same season	**SG 404 (0)**	**SG 84 (0)** **PR 47 (0)**	**535 (0)**
Year Discrepancies	**0**	**15**	**15**
Metal contamination	**695**	**299** pre-rinsed	**994**

Table 5. Recovery rate data for one year, two year and in season recoveries (Pacific herring CWT releases from 1999 to 2001). Pacific herring CWT releases. Table 5A. Raw data and recovery rates.

Data source	Recoveries	Release year	Tags released	Catch year	Screened tonnes	Recovery per release	Recovery per tonne
One year at large							
GS & QCI releases & screening 5 regions	127	1999	53,887	2000	6,222	0.2357%	0.020411
GS releases & GS + WCVI screening	122	1999	47,712	2000	3,515	0.2557%	0.034708
GS releases & GS screening	121	1999	47,712	2000	3,182	0.2536%	0.038026
QCI releases & QCI + CC screening	5	1999	6,175	2000	2,294	0.0810%	0.002180
QCI releases & QCI screening	4	1999	6,175	2000	138	0.0648%	0.028986
GS releases & GS + CC + PRD screening	334	2000	245,694	2001	6,922	0.1359%	0.048252
GS releases & GS + CC screening	334	2000	245,694	2001	6,646	0.1359%	0.050256
GS releases & GS screening	333	2000	245,694	2001	4,257	0.1355%	0.078224
Two year at large							
GS releases & GS + CC + PRD screening	97	1999	49,443	2001	6,922	0.1962%	0.014013
GS releases & GS screening	97	1999	43,266	2001	4,257	0.2242%	0.022786
no QCI fisheries in 2001	0	1999	6,175	2001	n/a	n/a	n/a
In-season							
GS releases & screening	404	2000	n/a	2000	3,182	n/a	0.126964
GS & PRD releases & screening	131	2001	n/a	2001	4,533	n/a	0.028899
GS releases & screening	84	2001	n/a	2001	4,257	n/a	0.019732
PRD releases & screening	47	2001	n/a	2001	276	n/a	0.170290

Table 6. Adjusted recovery rates and herring CWT harvest estimates (incorporating regional proportions of tonnes CWT screened from regional harvests).

Data source	Release year	Catch year	Screened / Harvested	Recovery per release	Recovery per tonne	CWT harvest estimates
One year at large recoveries						
GS & QCI releases & screening 5 regions	1999	2000	0.21368	1.1029%	0.09552	594
GS releases & GS + WCVI screening	1999	2000	0.22651	1.1289%	0.15323	539
GS releases & GS screening	1999	2000	0.23934	1.0596%	0.15888	506
QCI releases & QCI + CC screening	1999	2000	0.25129	0.3222%	0.00867	20
QCI releases & QCI screening	1999	2000	0.07823	0.8280%	0.37051	51
GS releases & GS + CC + PRD screening	2000	2001	0.28836	0.4714%	0.16733	1158
GS releases & GS + CC screening	2000	2001	0.31517	0.4313%	0.15946	1060
GS releases & GS screening	2000	2001	0.28462	0.4762%	0.27484	1170
Two year at large recoveries						
GS releases & GS + CC + PRD screening	1999	2001	0.28836	0.6804%	0.04860	336
GS releases & GS screening	1999	2001	0.28462	0.7877%	0.08006	341
no QCI fisheries in 2001	1999	2001	n/a	n/a	n/a	
In-season recoveries						
GS releases & screening	2000	2000	0.22651	n/a	0.56053	1784
GS & PRD releases & screening	2001	2001	0.23007	n/a	0.12561	569
GS releases & screening	2001	2001	0.28462	n/a	0.06933	295
PRD releases & screening	2001	2001	0.09462	n/a	1.79978	497

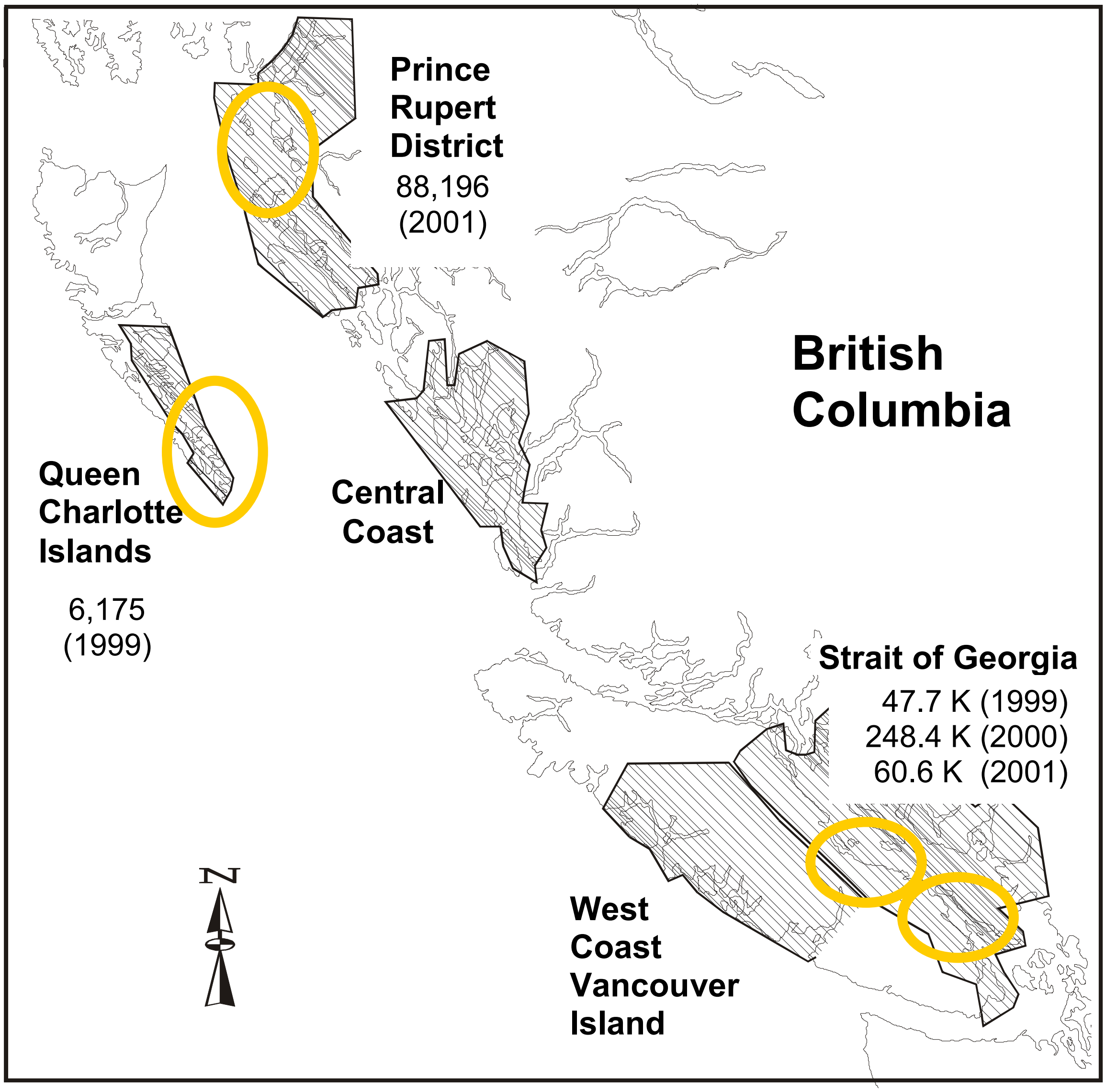

Figure 1. Pacific herring stock assessment regions in British Columbia (hashed areas) and CWT release coverage from 1999 to 2001(circled areas). For each region the number of tagged fish and year of release (bracketed) are noted. The total number of herring released with CWTs is approximately 450, 000.

Figure 2. Herring were dipnetted from a partially dried up purse seine for distribution to the tag injector stations.

Figure 3.
The central nape (neck) tag site and brass needle support are shown as a herring is about to have the needle inserted prior to tag insertion.

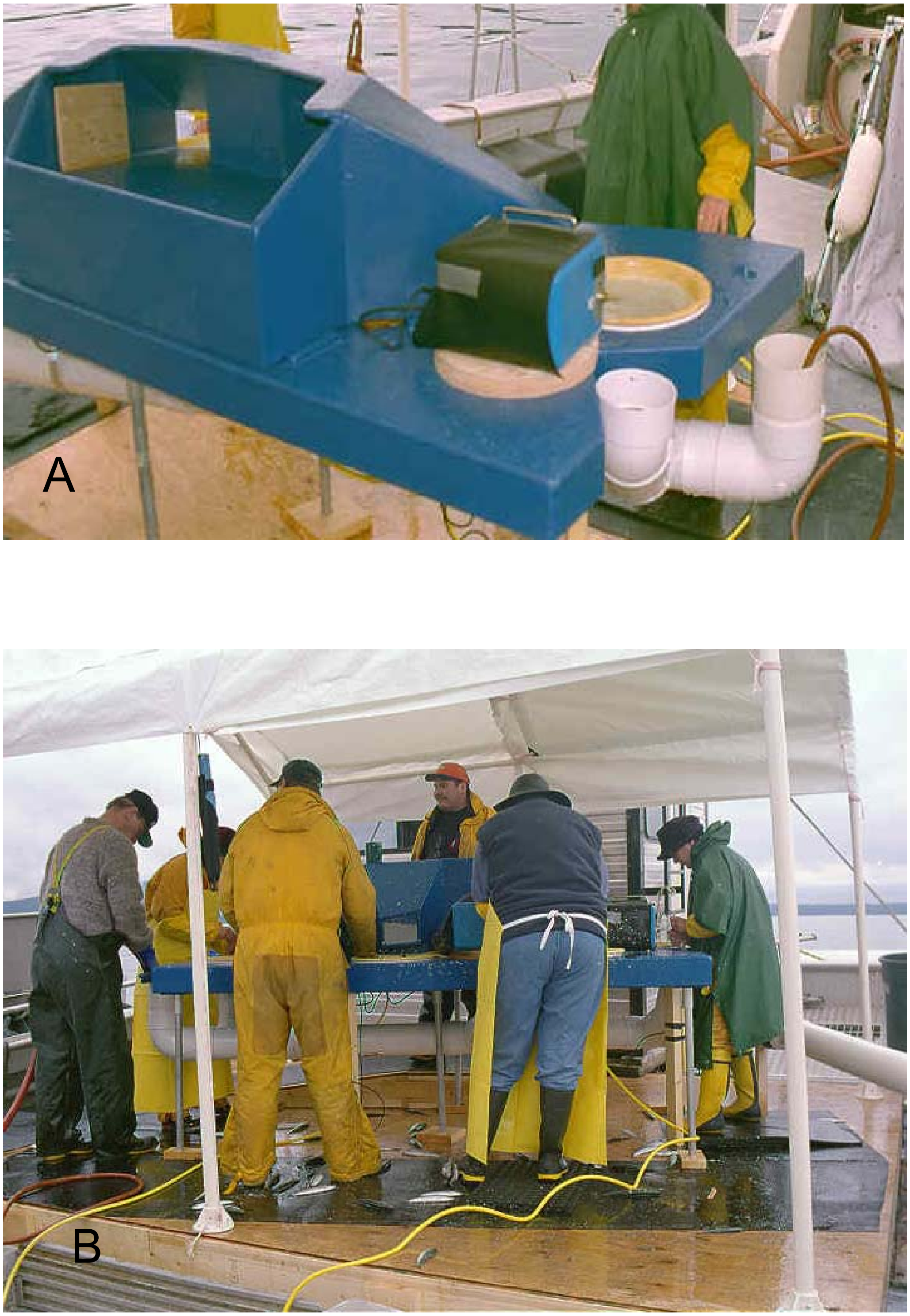

Figure 4 A and B. The tagging table used in 2000 and 2001 is shown with the upper manifold for receiving and distributing dipnets of herring to up to four tagging stations.

Figure 5. The tagging activities in 2000 and 2001 used a PVC piping system with flowing seawater to direct tagged fish overboard and a recovery pen was used to protect herring from predators.

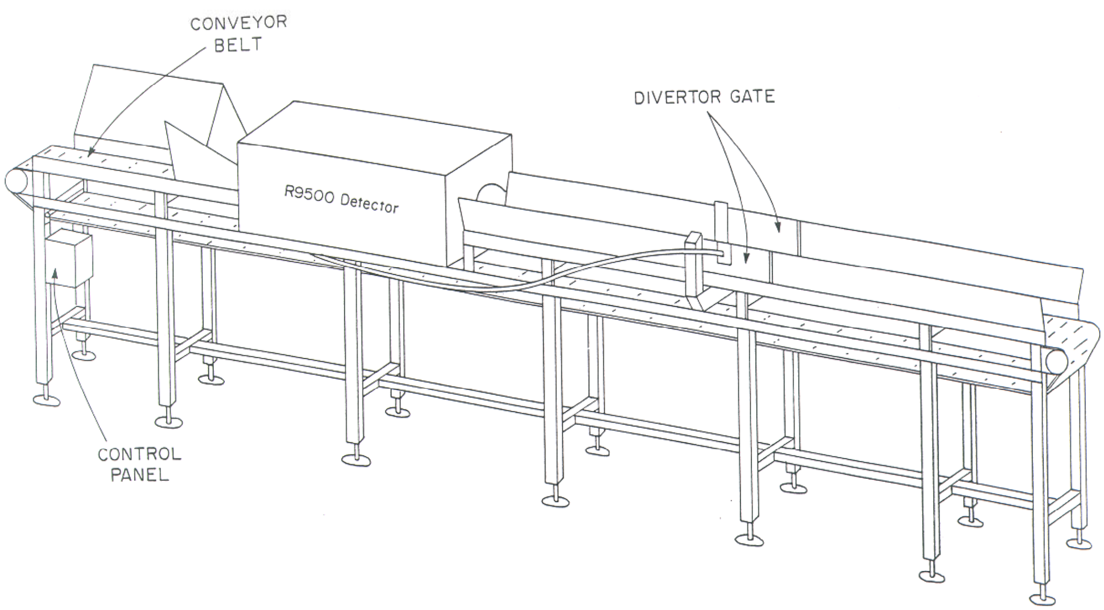

Figure 6. A depiction of a Pacific herring CWT recovery unit.

APPENDIX A

HOLDING TRIAL EXPERIMENTS WITH CODED WIRE TAGGED PACIFIC HERRING

INTRODUTION

Pacific herring holding trials were conducted to assess and compare the effects of CWT insertion on relative mortality, retention of tags and insertion of scales using three different tag insertion sites. The three tag sites were: the mid-dorsal (also referred to as the back site), the nape-centre (also referred to as the neck or middle neck site) and the nape-side (a newly designated insertion site). The mid-dorsal site was defined as the region within a 1.0 cm^2 area to the left of the mid-base of the dorsal fin. The nape-centre site was defined as the region within 2.0cm posterior to the skull along the longitudinal axis. The nape-side site was defined as the region approximately 1.0 to 2.0 cm to the left of the nape-centre site but approximately 0.5 to 1.0 cm posterior of the operculum cover. The duration of each set of holding trials following tagging treatments was three weeks, seven weeks or twelve weeks.

METHODS

Herring were caught by a commercial herring purse seine near Nanaimo, British Columbia, on November 13th, 2000. After fish were concentrated in the bunt of the seine net, brails of herring were gently placed into a live holding tank aboard a transport vessel. The size of the holding tank was 2.5 m by 2.5 m and 1.5 m deep and the travel time to the Pacific Biological Station was approximately 30 minutes. Fish and seawater were gently pumped through a flexible 30 cm diameter hose for 30 minutes to transfer herring into a stock holding pen of 7.6 x 7.6 m and 3.0 m deep. The herring were held in the stock pen until November 21st to recover from the stress of transport. One hundred and fifty herring from a random collection were processed for representative length and weight data (Figure A1). On November 21st, batches of herring were removed by dipnet from the stock pen and anaesthetised for approximately one minute with 100 ppm Tricaine methonosulfonate before being treated in one of five ways.

For each of the three holding periods (three, seven or twelve weeks) there were five sets of treatment groups, each with approximately 100 herring. For three of the treatments, herring received a CWT into one of the three tag sites as well as secondary markings (both an Elastomer tag and a pelvic fin clip). A marked control group was used whereby herring only received secondary markings and a negative control group was used whereby fish were neither tagged nor marked. Fish were tagged using Norwest Marine Technology CWT and Elastomer tag equipment. The CWT equipment and procedures were the same as for the field trials and secondary markings were used so that different treatment groups could share a pen and be distinguishable at the end of the trials. The secondary markings were green or red latex Elastomer tags (inserted into either the right or left jawbone) and a clipped pelvic fin (half of a right or left pelvic fin was clipped off with scissors), Table A1.

Trials used sea pens of size 3 m x 3 m and 6 m deep, which were enclosed with mesh covers to exclude predators. Mortalities were collected and immediately frozen at least three times a week and at the end of the experiment frozen samples were thawed and observations relating to tag insertion, secondary markings and scale embedding were made. At the end of each trial period, herring were euthanized in exposures of 250 ppm Tricaine methonosulphonate for greater than 5 minutes before specimens from different treatment groups were differentiated and analysed. A hand held CWT wand detector was used to determinek tag retention, tweezers were used to manipulate tissue and an illuminating 30 cm diameter magnifying glass was used to assess the absence or presence of secondary markings and scale embedding.

RESULTS AND DISCUSSION

Summary results of cumulative mortality, tag loss and scale insertion observations from the holding trials are presented in Table A2. After three weeks, tagged herring had from 5 to 12% mortality and the marked and negative control groups had 3 and 7% mortality, respectively. After seven weeks, tagged herring had approximately 14% mortality and the marked and negative control groups had 8 and 9% mortality, respectively. After twelve weeks, tagged herring had approximately 21% mortality and the marked and negative control groups had 18 and 14% mortality, respectively. Both types of secondary markings were apparent in mortalities and survivors and fish from different treatment groups were easily distinguishable. Overall delectability of Elastomer tags and fin clipping was 98% and 100%, respectively. Therefore, Elastomer tagging alone would have sufficed since fin clipping was used in case Elastomer tags failed. Coded wire tag retention was high for all trials and only three incidences of tag loss were observed (an overall incidence of 0.3% tag loss from approximately 900 tagged herring). Two incidences of tag loss were from herring tagged at the nape-centre site and one was from a specimen tagged at the mid-dorsal site. Only one of the nape-centre cases of tag loss was related to a mortality (observed at six weeks). Tag loss data are too sparse to assess the relative effects of insertion site or trial duration. Incidences of scale insertion ranged from 9 to 16% in the three week trials, from 6 to 9% in the seven week trials and from 5 to 6% in the twelve week trials.

The cumulative mortality data of the seven and twelve week trials suggest that trauma from CWT insertion and secondary markings contributed to mortality. In referring to the seven and twelve week mortality data only, the percent differences in mortality between the tagged and control groups ranged from 3 to 7%. This 3 to 7% range may even be an overestimate for describing the effects of CWT insertion because the differences incorporate effects from fin clipping and Elastomer tagging. One obvious difference between the sea pen trials and CWT fieldwork is that the sea pen trials were done outside of the spawning season. Although a 3 to 7% increase in mortality due to tag insertion would be a relatively small imposition on wild herring, this range does not describe differences in mortality occurring between handling and tagging sexually ripe fish and leaving sexually ripe fish completely undisturbed. The holding trials were purposely scheduled outside of the spawning season to avoid problems (such as microbiological growth and poor water quality) associated with herring spawning in the pens. However, the holding experiment still could have introduced unnatural stresses that affected mortality through challenging tissue healing at CWT insertion sites, Elastomer tags sites and clipped fins. Also, an element of starvation was possible since no food was provided other than what passed into the pens from the ambient marine environment.

No apparent differences in mortality, tag retention or scale insertion were found among the three tag insertion sites for comparing application advantages or disadvantages. Also, the ease with which CWTs can be inserted into each of the three body sites is comparable. However, there are other reasons for selecting a tag insertion site for field application. One of which relates to acquiring age information from otoliths. Mid-dorsal recoveries can not provide otoliths because roe processing in the fish plants cuts herring bodies in half along the medial axis before they are screened for CWTs. Secondly, there is a small chance that CWTs inserted in the mid-dorsal site may be displaced or lost from medial cutting. The results of the holding trials have also been informative in suggesting that the nape-centre and nape-side sites may be equally effective. The practicality of this is that if people conducting the field tagging inadvertently tag the nape-side while aiming for the nape-centre, there would be no adverse consequence affecting recovery. It is not clear whether inadvertently inserting a scale during CWT insertion is harmful to herring because mortality from scale insertion cannot be distinguished from CWT insertion. It is possible that scale insertion has minimal impact on fish health because the differences in mortality between tagged and untagged herring were relatively small.

The holding trials were helpful in providing some mortality estimates for considering the effects of CWT insertion and showing that there were negligible fish health benefits between the choice of tag insertion sites. The low incidence of tag loss was very encouraging since tag loss and mortality both reduce tag recovery opportunities in any mark and recapture program. The two nape tag insertion sites appear to be most practical and are recommended for future Pacific herring CWT and release work.

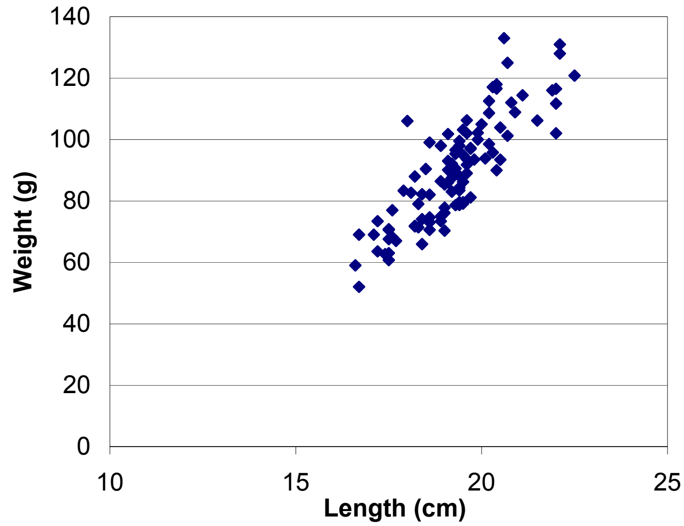

Figure A1. Representative length and weight data from a random sample of 150 Pacific herring sacrificed on November 21st 2000 in association with the specimens used in the multiple week holding trials at the Pacific Biological Station in Nanaimo, British Columbia. Sample means were: length 89.8 cm (StD 17.6) and weight 19.3 g (StD 1.3) and 59% were male.

Table A1. Markings used to differentiate herring among treatment groups within each of the holding trials. L= left side; R= right side.

Treatment group	Fin clip	Elastomer tag	Approximate sample size
Negative control	--	--	100
Marked control	L	L & red	100
Nape-centre	R	R & green	100
Nape-side	L	L & green	100
Mid-dorsal	R	R & red	100

Table A2. Results of holding trials to evaluate effects of coded wire tag insertion on adult Pacific herring. Trials started on November 21st, 2000 at the Pacific Biological Station in Nanaimo, British Columbia. For each case with CWT loss, m= mortality; s= survivor.

Treatments	n	Cumulative mortality	CWT loss	Grossly visible insertion of scale
3 week trials	**N=495**			
Negative control	98	7	N/A	N/A
Marked control	99	3	N/A	N/A
Nape-centre	99	5	0	9
Nape side	100	5	0	16
Mid-dorsal	99	12	0	10
7 week trials	**N = 498**			
Negative control	98	9	N/A	N/A
Marked control	101	8	N/A	N/A
Nape-centre	99	14	1 **m**	6
Nape side	101	14	0	9
Mid-dorsal	99	14	0	6
12 week trials	**N=495**			
Negative control	102	14	N/A	N/A
Marked control	95	17	N/A	N/A
Nape-centre	98	21	1 **s**	5
Nape side	101	20	0	6
Mid-dorsal	99	21	1 **s**	6